DEPARTMENT OF THE INTERIOR

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MORPHOMETRIC COMPARISON OF TECTONICALLY DEFINED AREAS WITHIN THE WEST-CENTRAL BASIN AND RANGE, CALIFORNIA AND NEVADA

by

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ABSTRACT

It is generally recognized that the geomorphic framework of the Basin and Range province is largely the product of regionally distributed, middle to late Cenozoic, extensional tectonism. However, recent work suggests that the timing and style of this regional extension has varied widely and that the province is an irregular mosaic of more or less independent tectonic domains. Portions of five major tectonic domains (central Great Basin, southeast Great Basin, Walker Lane belt, southwest Great Basin, and northern Mojave Desert) make up the west-central part of the Basin and Range, and preliminary geomorphic analysis documents systematic morphometric differences between these domains. These differences likely reflect regional differences in the timing and style of Cenozoic extension. They suggest that: (1) domains of high vertical tectonic activity may be juxtaposed against domains of low vertical tectonic activity; (2) various parts of the Walker Lane belt have undergone very different histories and (or) styles of extensional deformation; (3) the southwest Great Basin is the most active domain within the west-central Basin and Range; and (4) the northeast part of the Goldfield block of the Walker Lane belt and the northern Mojave Desert are the least active areas within this region. These results suggest that regional morphometric and geomorphic comparisons may prove fruitful for analyzing the neotectonic history of the Basin and Range.

INTRODUCTION

Generally defined, the Basin and Range Province is that area of southwestern North America that is characterized by more or less regularly spaced, subparallel mountain ranges and intervening alluviated basins formed by extensional faulting. Within the United States, the province describes an irregular arcuate-shaped region that curves around the western and southern margins of the Colorado Plateau and extends westward to the Transverse Ranges, Sierra Nevada and southern Cascade Range of eastern California (Hunt, 1974) (Fig. 1). The geology of the province can be generalized as a latest Precambrian and Paleozoic continental margin assemblege (grading from miogeoclinal strata on the east to eugeoclinal strata on the west) that was complexly deformed by late Paleozoic to early Mesozoic orogenies, intruded in western areas by Mesozoic granitic rocks, broadly overlain by Cenozoic volcanic rocks, and extensively deformed by middle to late Cenozoic extensional tectonism (Stewart, 1978; 1980a). This Cenozoic deformation, which is responsible for the salient physiographic characteristics of the province (e.g. the size, shape, orientation, and spatial distribution of the basins and ranges), occurred in two distinct phases (Shafiquallah and others, 1980; Zoback and others, 1981, Reynolds and Spencer, 1985): (1) an Oligocene to mid-Miocene period of large magnitude ENE-WSW crustal extension characterized by low-angle detachment faulting and the formation of metamorphic core complexes, and (2) continuing from middle Miocene time to the present, a subsequent period of lesser magnitude ESE-WNW extension characterized by 'basin and range' high-angle normal faulting and the formation of large fault-block ranges.

Extension of the Basin and Range Province is being driven by the northward rotation of the Pacific plate relative to the North America plate about a pole near 50°N and 70°W (Atwater, 1970; Minster and Jordan, 1978), and it has been suggested that the province is growing northward as the Mendocino triple junction migrates with this plate rotation (Dickinson and Snyder, 1979). Movement along the San Andreas fault, the complex continent-continent transform boundary between these two plates, appears to have been constant during the last 4-5 m.y. (Weldon, 1985). This implies a stable orientation of regionally applied stress in the southwest Basin and Range throughout latest Cenozoic time. However, this applied stress has interacted with an inhomogenous crust to produce a mosaic of structurally and physiographically distinct domains separated by major zones of weakness (Fig. 1), and deformation within each of these domains appears to have proceeded more or less independently of adjacent areas (Stewart, 1987).

Tectonic Domains of the West-Central Basin and Range

Portions of at least five major tectonic domains make up the west-central Basin and Range: the central Great Basin, the southeast Great Basin, the Walker Lane Belt, the southwest Great Basin, and the northern Mojave Desert (Fig. 1). In the western part of the region, these domains are separated from each other and from adjacent physiographic provinces by major Quaternary strike-slip fault zones; however in the eastern part, domain boundaries are not clearly related to discrete Quaternary structures.

Central Great Basin - The massive north- to northeast-trending ranges and basins of the central Great Basin extend across the elevated central portion of the Great Basin. These ranges, among the largest in the Basin and Range, display clear and abundant geomorphologic evidence of active range-front faulting (Bull, 1984; Dohrenwend, unpublished data). Along the western edge of this domain, extensive surface faulting has occurred in association with four historic earthquakes (Callaghan and Gianella, 1935; Slemmons, 1957; Stewart, 1980a, p. 119). This region is bounded on its western margin by the strike-slip fault zones of the Walker Lane belt and on its southwest margin by a prominent structural discontinuity separating west-tilted ranges to the north from east-tilted ranges to the south (Stewart and Johannesen, 1979; Stewart, 1980b). However, the southern boundary does not appear to coincide with any conspicuous structural trend.

Southeast Great Basin - The southeast Great Basin presents a distinct contrast with the central Great Basin. Both the basins and ranges of the southeast Great Basin are significantly smaller than those further north; and the ranges are more closely spaced. Compared with the other tectonic domains of the west-central Basin and Range, the boundaries of the southeast Great Basin are indistinct and poorly defined. However, the western margin of the region generally corresponds with the eastern edge of the Walker Lane belt and the southwest boundary is defined by the Las Vegas shear zone.

Walker Lane Belt - The Walker Lane belt is a complex zone of strike-slip displacement that subparallels the western margin of the Great Basin from the area of Pyramid Lake in northwest Nevada to the Mojave Desert (Carr, 1984). This northwest-trending zone, 80 to 150 km wide and about 700 km long, is made up of at least 8 major structural blocks each of which has acted more or less independently of adjacent blocks. Three of these blocks are situated in the west-central Basin and Range: the Goldfield block, the Spotted Range-Mine Mountain block, and the Spring Mountains block (Carr, 1984; Stewart, 1987).

Southwest Great Basin - The southwest Great Basin, the Inyo-Mono block of Carr (1984) and Stewart (1987), is a roughly triangular area of about 25,000 km^2 that is bounded on the west by the complex Owens Valley-White Mountains fault zone, on the south by the Garlock fault zone, and on the northeast by the Death Valley and Furnace Creek fault zones of the Walker Lane. This area is transitional between the high strain rate, strike-slip movement of the North American-Pacific plate boundary and the predominantly low strain rate, high angle normal fault movement of the central Great Basin. It is one of the most tectonically active sections of the Basin and Range Province (Bull and McFadden, 1977; Bull, 1977), and it is characterized by both normal and strike-slip fault displacements (Roquemore, 1980; Carr, 1984; Stewart, 1987).

Northern Mojave Desert - South of the Garlock fault zone, the Mojave Desert is bounded on the southwest by the San Andreas fault zone and the Salton Trough, and on the east by the valley of the Colorado River. Compared with the actively extending southwest Great Basin, the landscape of the Mojave Desert is subdued. With the exception of a prominent set of northwest-trending right-lateral faults that transects its south-central part, the region is largely lacking in morphologic evidence of active tectonism (Bull and McFadden, 1977); however, despite this general lack of tectonic activity, drainage is still largely internal and the Mojave River system is the only significant regional drainage.

Purpose and Scope

This paper presents a preliminary morphometric comparison of the several neotectonic domains that make up the west-central Basin and Range. The morphometric properties of all major landscape elements (with areas greater than 10 km^2) are summarized for each domain. On the basis of these morphometric summaries, the domains are morphologically compared and their relative level of neotectonic activity inferred. The implications of these results relative to general patterns of late Cenozoic tectonic history are then briefly discussed.

PROCEDURE

Area of Analysis

The west central Basin and Range is herein defined as that area of the Basin and Range geomorphic province between 35° and 39° N latitude and west of 115° W longitude (Fig. 2). It includes the northern part of the Mojave Desert subprovince and most of the southern part of the Great Basin subprovince, including the southwest Great Basin and portions of the central Great Basin, southeast Great Basin, and Walker Lane belt.

Data Sources and Measurements

Morphometric measurements were obtained from 1:250,000-scale, 200-foot contour, U. S. Geological Survey topographic maps (Fig. 2). These maps represent an accurate, consistent, and readily available data source that is ideally suited for

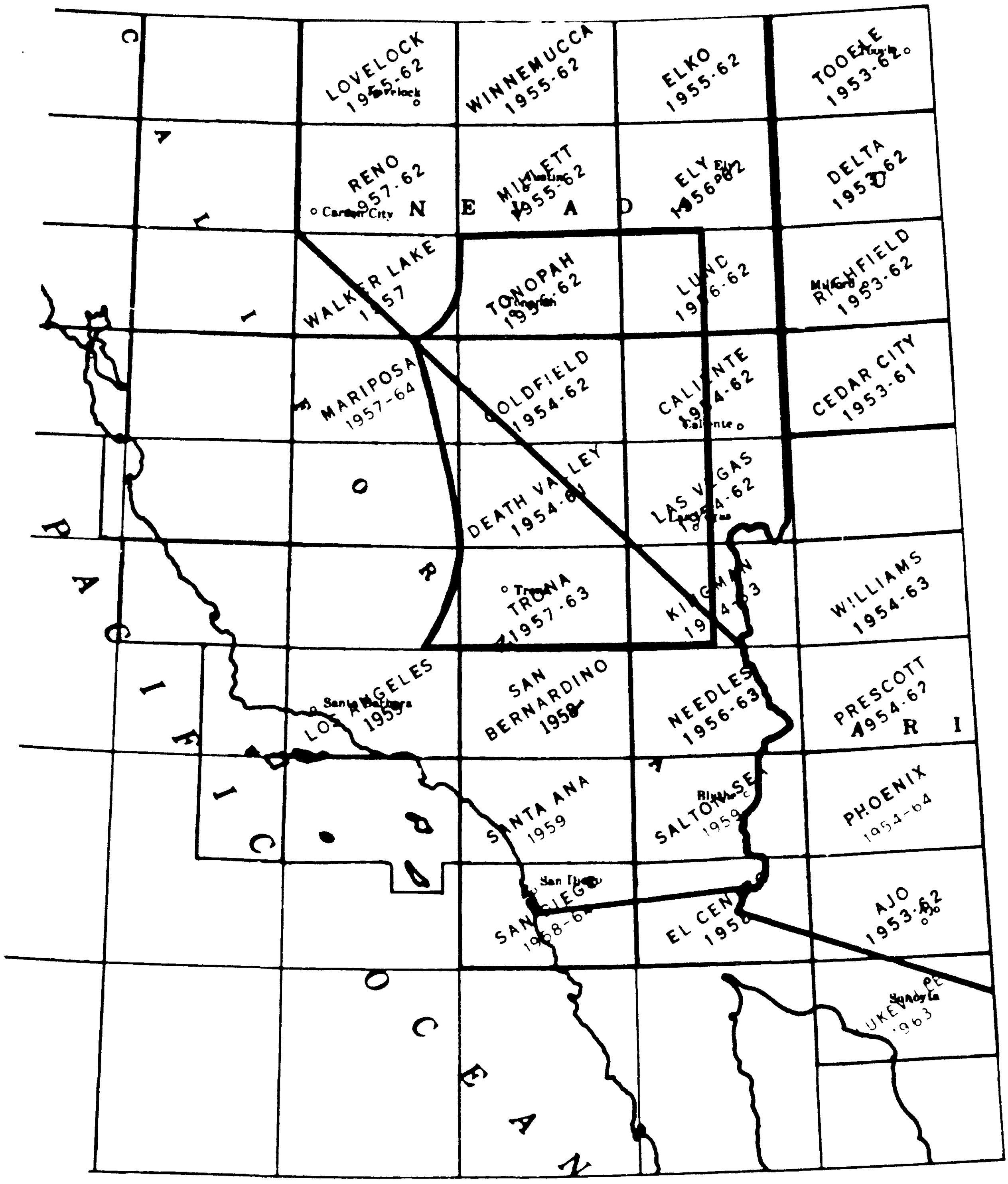

Figure 2. Area of morphometric analysis. The area of this preliminary analysis encompasses that part of the Basin and Range Province between 35° and 39° N latitude and west of 115° W longitude. This area is shown on nine 1:250,000-scale topographic quadrangles: Caliente, Death Valley, Goldfield, Kingman, Las Vegas, Lund, Mariposa, Tonopah, and Trona.

regional geomorphic analyses. They present a quantitative regional generalization of topography that filters extraneous geomorphic detail but retains essential morphometric information. Areas were measured to an accuracy of about ± 3% using a compensating polar planimeter. Horizontal distances were measured to an accuracy of approximately ± 0.6 cm (1.5 km); and vertical distances were estimated directly from the topographic maps to an accuracy of approximately ± 30m.

DEFINITIONS

Terrain Categories

For the purposes of this general regional analysis, the landscape of the west-central Basin and Range can be divided into three general terrain categories: ranges, piedmonts, and basin floors (Figs. 3 and 4).

Ranges - The ranges are predominantly areas of high relief and steep slopes underlain by consolidated bedrock that has been deeply dissected by fluvial erosion. They range from low ridges and small hilly areas a few km in length and width to massive ranges as much as 150 km long and 25 km wide that locally rise more than 3000 m above adjacent basins.

Piedmonts - The piedmonts are moderately to gently sloping surfaces of moderate overall relief and low local relief. Piedmont slopes commonly average between 3 and 5 percent and are generally less than 15 percent, although slopes of as much as 35 percent occur locally along some of the more active range fronts. Piedmont surfaces are complex mosaics of fluvial erosion and deposition; upper piedmonts are commonly areas of degradation and transportation whereas lower piedmonts are predominantly areas of aggradation. Piedmont surfaces are commonly buried by discontinuous veneers of eolian fine sand and silt. They may be underlain by either consolidated bedrock (pediments) or unconsolidated alluvium (bajadas).

Basin Floors - In closed basins, basin floors are aggradational surfaces of low relief where overall slopes rarely exceed 0.5°. Locally, they may be shallowly dissected by fluvial incision (and (or) deflation) or buried by eolian deposition. These

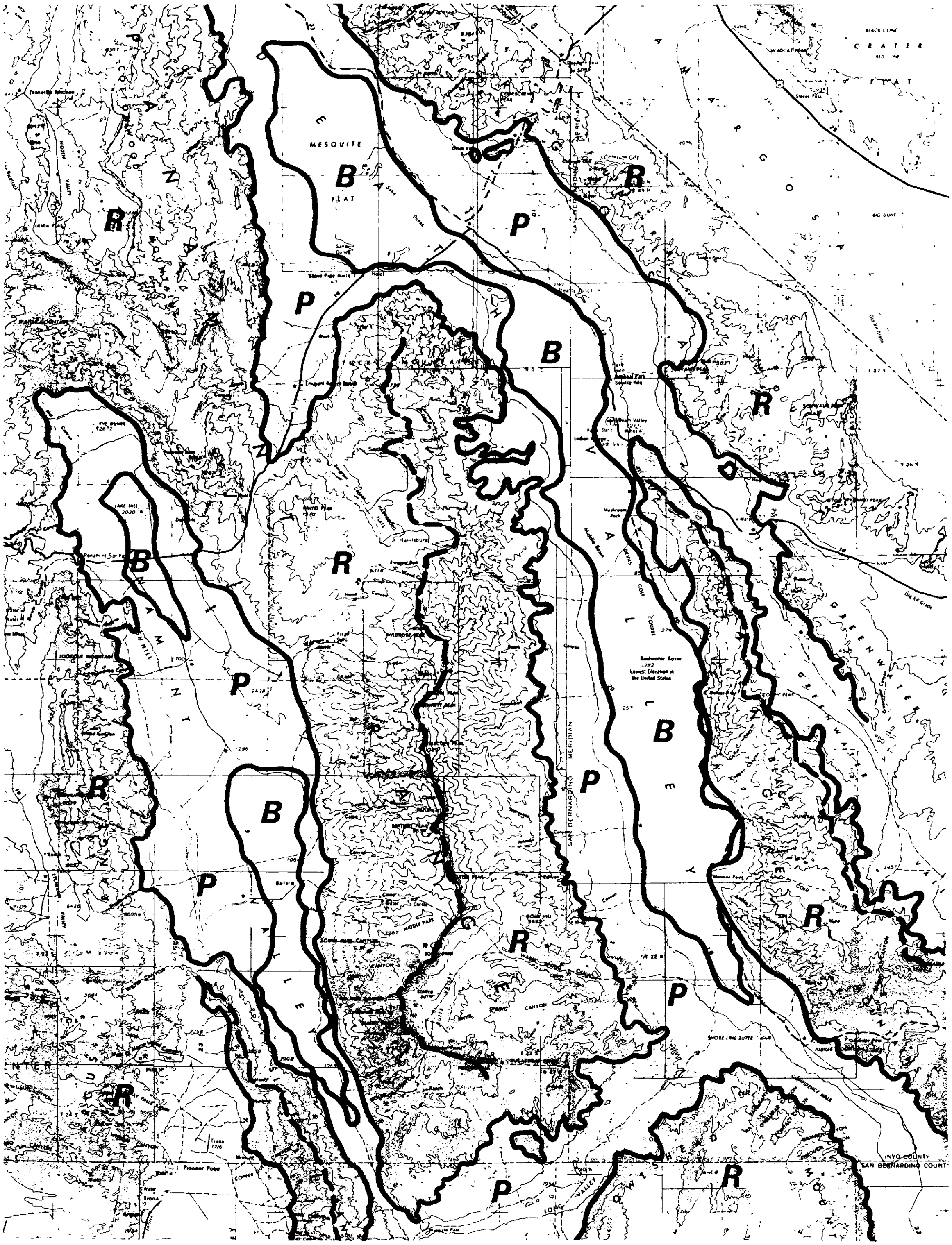

Figure 3. Topographic map showing terrain boundaries for an area of the southwest Great Basin. R = range, P = piedmont, B = basin floor, solid lines = terrain boundaries, dashed lines = range crests.

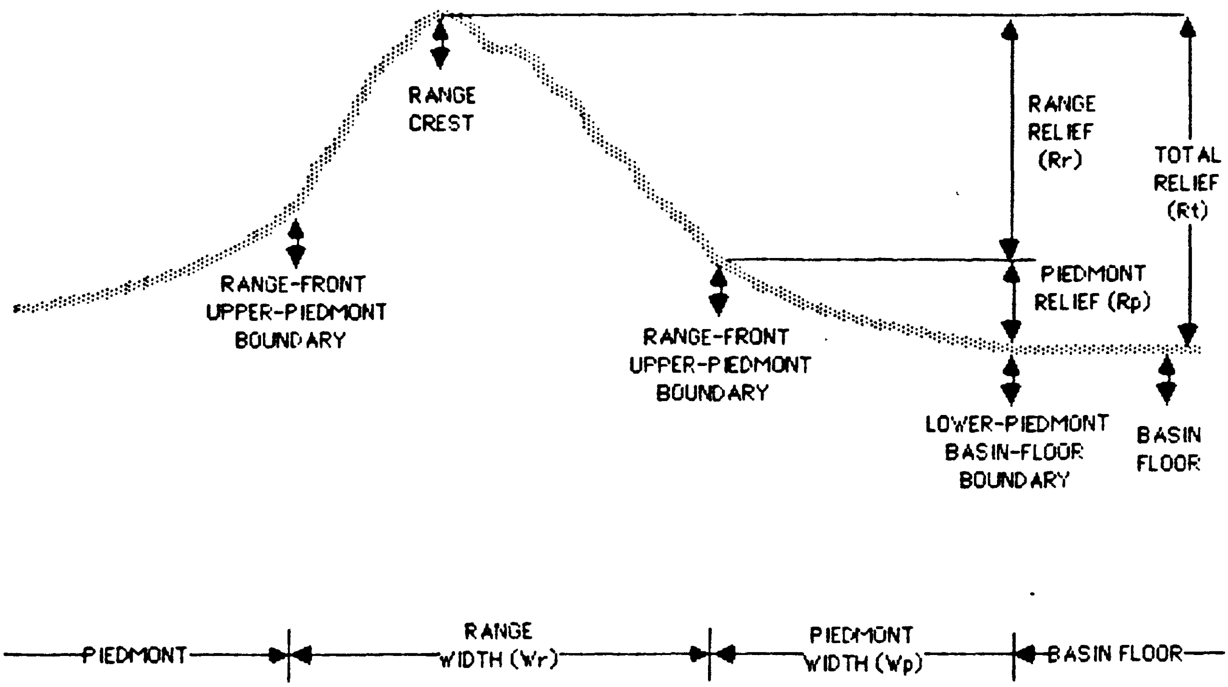

Figure 4. Diagramatic cross-section illustrating various range and piedmont boundaries and dimensions.

surfaces are intermittently flooded and typically are underlain by intercalated lacustrine, playa, distal fan, and eolian deposits. Open basins generally lack these flat floors and commonly are moderately to deeply dissected by intermittent axial drainage.

Terrain Boundaries

Consistent measurement of these general terrain categories requires unambiguous definition of terrain boundaries (Figs. 3 and 4).

Range-Front/Upper-Piedmont Boundary - The range-front/upper-piedmont boundary is defined as the conspicuous break in slope between the range front and the upper piedmont (Fig. 4). Range-front slopes generally average 40 percent or more, whereas upper piedmont slopes seldom exceed 25 percent. For most ranges in the west-central Basin and Range, this transition averages substantially less than a few hundred meters in width. On 1:250,000 topographic maps, it is expressed as an abrupt change in contour spacing that in most cases can be objectively and consistently located to within ± 0.5 km (Fig. 3).

Lower-Piedmont/Basin-Floor Boundary - The lower-piedmont/basin-floor boundary is marked by a somewhat less distinct break in slope (Fig. 4). Distal piedmont slopes generally range between 1° and 3°, whereas basin floor slopes are commonly less than 0.5°. In many areas, the transition between distal piedmont areas and the basin floor is smooth and gradual. On 1:250,000 contour maps, it is usually expressed as a slight but distinct change in contour spacing; however, because of the 200-foot contour interval of these maps, the actual boundary commonly can be only generally located to within about ± 2 km (Fig. 3). Therefore for the purposes of this analysis, the lower-piedmont/basin-floor boundary is arbitrarily placed just basinward of the lowest contour with form and spacing similar to those contours that define the main body of the piedmont (Fig. 3).

Morphometric Parameters

Range - For the purposes of this analysis, an individual mountain range is defined as an upland area of more than 10 km^2 that is almost entirely bounded by and upslope from piedmonts and (or) basin floors. It may be a continuous range (a single uninterrupted upland area), a discontinuous range (a group of upland areas where each is separated by no more than 5 km from an adjacent upland), or one of two or more contiguous uplands (adjoining uplands of substantially different structural style or orientation).

Range Length - Range length is the length of the range axis (where the range axis is defined by the midpoints of lines drawn across the range perpendicular to the average range trend).

Range Width - Average range width is defined as range area divided by range length.

Range-Crest Elevation - Range-crest elevation is defined as the average crestal elevation of the range. It is approximated by the mean of elevation measurements taken at 10-km intervals along the range crest (and so positioned as to include the point of highest elevation in the range).

Range Relief - Range relief is defined as the average change in elevation between the base of a range and its crest. It is approximated by the mean of measurements of this elevation difference spaced at 10-km intervals along the range crest (and so positioned as to include the point of highest elevation in the range).

Piedmont Width - Piedmont width is the average width of the piedmont as determined from the mean of measurements spaced at 10-km intervals along the range front.

Piedmont Relief - Piedmont relief is defined as the average change in elevation between the range-front boundary and the basin-floor boundary. It is approximated by the mean of measurements of this elevation difference spaced at 10-km intervals along the range front.

Piedmont Slope - Piedmont slope is defined as the general basinward slope of a piedmont area. Piedmont slope equals piedmont relief divided by piedmont width.

Total Relief - Total relief is defined as the average elevation difference between a range crest and adjacent basin floors. Total relief is the sum of range relief and piedmont relief.

Range Spacing - Range spacing is defined as the average horizontal distance between the crests of adjacent ranges. It is approximated by the mean of measurements spaced at 10 or 20 km intervals (depending on range length) along the axis of the intervening basin.

Basin Closure - Basin closure is defined as the difference in elevation between the lowest subaerial point within a closed basin and the lowest point on the drainage divide enclosing that basin.

SOURCES OF ERROR

Several sources of error are involved in estimating the general morphometric properties defined above. (1) Perhaps the most significant source of error is inherent in the natural complexity of the landscape and the intentional simplicity of the morphometric parameters used to characterize that landscape. Average values of measurements taken at discrete locations can, at best, only crudely approximate actual values of continuous and highly variable morphologic characteristics such as range relief or piedmont slope. (2) Measurement error represents another potentially significant source of error. Area measurements were estimated with a compensating polar planimeter; repetitive area measurements were generally reproducible to within ± 3%. Linear measurements were made with a flexible scale and were rounded to the nearest 0.4 cm (representing 1.0 km at 1:250,000 scale); therefore, these measurements are generally accurate to within ± 1.0 km. These limits of accuracy are more than adequate for general morphometric analysis of a 100,000 km^2 region. (3) Another source of error arises from the use of 1:250,000-scale, 200-foot contour maps as the basic data source. These maps are approximate and highly generalized models of the real landscape. Location of the terrain boundaries on these maps can only be accomplished within approximate limits. Therefore, all measurements dependent upon these terrain boundaries can only be as accurate as the approximate positions of the boundaries themselves. However, this uncertainty is judged to be substantially less than the uncertainties involved with (1) and (2) above.

MORPHOMETRIC SUMMARY OF THE WEST-CENTRAL BASIN AND RANGE

The general morphometric characteristics of the major landscape elements within the west-central Basin and Range Province are summarized in Tables 1, 2, and 3. Table 1 presents total areas and average proportions of the general terrain categories (ranges, piedmonts, and basins) for each tectonic domain. Table 2 lists average elevations of range crests and basin floors and average values of range and piedmont relief within each domain. Table 3 summarizes the average dimensions of the ranges and piedmonts within each domain.

Expected Geomorphic Trends

The geomorphic framework of the Basin and Range Province is largely the product of middle to late Cenozoic extensional tectonism, and systematic morphometric differences between the various parts of this province are almost certainly related to temporal and spatial variations in the timing and style of this tectonic activity. The condition of the landscape at any point in time is the net result of the constructional processes (i.e. tectonic processes) that have acted to form the primary landscape elements (i. e. the basins and ranges) and the erosional processes that have acted to degrade these constructional forms. For example, ranges that have recently undergone high rates of relative uplift are likely to be less degraded than ranges that have been relatively stable during the past several milion years. Therefore, when comparing areas of similar tectonic style, ranges are likely to be proportionally larger and more continuous, piedmonts are likely to be proportionally smaller and less continuous, and basins are likely to be deeper and more isolated within younger and (or) more active tectonic domains. Also, values of range area, range width, range-relief-to-total-relief ratios (Rr/Rt), and basin closure should be larger and

Table 1. Morphometric summary of the West-Central Basin and Range: total areas and average proportions of terrain categories

Tectonic Domain	Total Area	Range Area		Piedmont Area		Basin Area	
	(km²)	(km²)	(%)	(km²)	(%)	(km)	(%)
Central Great Basin	24,850	10,525	42.3	11,825	47.6	2,520	10.1
Southeast Great Basin	22,650	8,350	36.9	12,040	53.1	2,260	10.0
Walker Lane Belt							
- Northwest Goldfield Block	7,310	2,935	40.2	3,420	46.8	955	13.0
- Northeast Goldfield Block	8,105	1,565	19.3	4,425	54.6	2,115	26.1
- Spotted Range-Mine Mtn. Block	1,940	560	28.8	1,270	65.3	114	5.9
- Spring Mountains Block	4,675	2,335	50.0	2,340	50.0	-	-
Southwest Great Basin	25,630	13,595	53.0	9,825	38.4	2,210	8.6
Northern Mojave Desert	19,710	5,600	28.4	12,625	64.1	1,485	7.5

Table 2. Morphometric summary of the West-Central Basin and Range: average elevations and average relief

Tectonic Domain	Range Elevation (m)	Basin Elevation (m)	Total Relief (Rt) (m)	Range Relief (Rr) (m)	Rr/Rt	Piedmont Relief (Rp) (m)	Rp/Rt	Basin Closure (m)
Central Great Basin	2,625	1,695	930	725	0.78	205	0.22	170
Southeast Great Basin	2,135	1,265	870	630	0.72	240	0.28	205
Walker Lane Belt								
- Northwest Goldfield Block	2,290	1,390	900	635	0.71	265	0.29	130
- Northeast Goldfield Block	2,045	1,320	725	490	0.68	235	0.32	90
- Spotted Range-Mine Mtn. Block	1,645	1,065	580	390	0.67	190	0.33	100
- Spring Mountains Block	2,390	690	1700	1190	0.70	510	0.30	-
Southwest Great Basin	2,065	395	1670	1380	0.83	290	0.17	632
Northern Mojave Desert	1,550	765	785	485	0.62	300	0.38	135

Table 3. Morphometric summary of the West-Central Basin and Range: average range and piedmont dimensions

Tectonic Domain	Range Area (km^2)	Range Length (Lr) (km)	Range Width (Wr) (km)	$\frac{Lr}{Wr}$	Piedmont Width (Wp) (km)	$\frac{2Wp}{Wr}$	Piedmont Slope (%)	Range Spacing (km)
Central Great Basin	1446	111.9	12.4	9.6	5.9	0.95	3.6	26.2
Southeast Great Basin	388	56.2	6.3	9.4	6.0	1.90	4.0	20.0
Walker Lane Belt								
- Northwest Goldfield Block	244	30.8	6.6	5.5	6.1	1.85	4.4	17.5
- Northeast Goldfield Block	147	19.3	6.5	4.4	7.7	2.34	3.0	30.9
- Spotted Range Mine Mtn. Block	71	19.6	2.3	5.8	4.5	3.91	4.3	9.5
- Spring Mtns. Block	2232	126.4	18.5	6.8	11.9	1.29	4.3	-
Southwest Great Basin	1130	78.0	13.8	6.3	4.9	0.71	6.3	23.0
Northern Mojave Desert	160	25.8	5.7	4.4	8.2	2.88	3.7	19.6

values of piedmont-width-to-range-width ratios (2Wp/Wr), and piedmont-relief-to-total-relief ratios (Rp/Rt) should be smaller in these more active domains. However, when comparing areas of differing tectonic style but similar age, ranges produced by shallow detachment-style extension are likely to be smaller, lower, and more closely spaced than ranges produced by more deeply penetrating 'basin-range'-style, high-angle normal faulting (Zoback and others, 1981, Eaton, 1982).

Domain Comparisons

Central Great Basin - The central Great Basin (CGB, Fig. 1), which has the highest average elevation in the west-central Basin and Range, displays a youthful landscape that is clearly dominated by the effects of high-angle normal faulting. Although many basins within this domain drain to one or the other of two major drainage systems, nearly 40 percent are closed with an average depth of closure of 170 m. Moreover, the massive north- to northeast-trending ranges of the area are among the largest in the Basin and Range. Markedly elongate with average length-to-width ratios (Lr/Wr) of 9.6, these ranges average 1446 km^2 in area, 112 km in length, and 12.4 km in width. Range spacing averages more than 26 km, and represents the largest average spacing within any of the major tectonic domains of the west-central Basin and Range. Range-relief-to-total-relief ratios (Rr/Rt) are high, piedmont-width-to-range-width ratios (2Wp/Wr) are low, and the ranges occupy more than 40 percent of the domain. Range fronts are generally linear to curvilinear in overall plan form and only slightly to moderately sinuous (Bull, 1984); and geomorphic evidence of active range-front faulting (including faceted spurs, 'wine-glass' valleys, and fault scarps cutting Quaternary alluvium) is abundant and well developed (Dohrenwend, unpublished data).

Southeast Great Basin - The southeast Great Basin (SEGB, Fig. 1) presents a clear contrast to the central Great Basin. The distinctly curvilinear ranges of this domain are substantially smaller than those of the central Great Basin. Range lengths and widths average only about 50 percent and range areas average only slightly more than 25 percent of those further north. Also these ranges are more closely spaced, with average range spacing about 30 percent less than in the central Great Basin. These contrasts suggest the possibility of significantly different tectonic styles between the two domains, perhaps involving differences in the depth or type of deep crustal extension. However, other morphometric characteristics (including range relief, piedmont relief, piedmont width and slope, and basin closure) are very similar between the two domains, suggesting generally comparable levels of neotectonic activity (i.e. similar timing and rates of late Cenozoic deformation).

Walker Lane Belt - The Walker Lane belt, a complex zone of strike-slip displacement that subparallels the western margin of the Great Basin, is made up of at least 8 major structural blocks (Carr, 1984, Stewart, 1987). Three of these blocks (the Goldfield block, the Spotted Range-Mine Mountain block, and the Spring Mountains block) are located in the area considered by this analysis.

Goldfield Block - The Goldfield block occupies an elongate, northwest-trending area of approximately 22,000 km^2. This portion of the Walker Lane belt is unusual in that it lacks both major northwest-trending strike-slip faults and major basin-range faults (Stewart, 1987). The topography of the Goldfield block is variable, and the block can be divided into four physiographically distinct sections (Fig. 1): irregular basins and ranges of the northwest part (NWG), broad irregular basins and low discontinuous ranges of the northeast part (NEG), irregularly-shaped volcanic plateaus (VP) of the central and southeast parts, and the broad, northwest-trending basin of the Amargosa Desert (AD) along its southwestern edge. Because the southern part of the block is dominated by volcanic plateaus which are more or less unique in the west-central Basin and Range, only its northwest and northeast parts are considered in this preliminary analysis of basin and range morphometry.

Northwest Goldfield block - The northwest Goldfield block (NWG, Fig. 1) is an elongate, northwest-trending zone, 40 to 60 km wide, that lies along the California-Nevada border in the western Great Basin. In many respects, this area is morphometrically similar to the southeast Great Basin; mean values of range relief, piedmont relief, width, and slope, and range spacing are approximately the same for both areas. However, the ranges of the northwest Goldfield block are highly variable in trend and highly irregular in overall plan; and the area lacks the pervasive, generally north-trending structural grain that characterizes most of the Great Basin.

Northeast Goldfield block - In contrast, the northeast part of the Goldfield block (NEG, Fig. 1) is characterized by the most subdued physiography in the southern Great Basin. Ranges are small, low, and discontinuous; and the irregular range fronts suggest an almost complete lack (or at most a very low level) of vertical range-front faulting. Indeed, this area is more like the northern Mojave Desert than any other area of the southern Great Basin. Mean values of range area, length, width, and relief, and of piedmont relief, width, and slope are nearly identical in these two widely separated areas. With the exception of the Spotted Range-Mine Mountain block, ranges are smaller and lower and piedmonts are broader and more gently sloping than in any other area of the southern Great Basin. Moreover, the relative proportions of ranges and basins also suggest little vertical tectonic activity. Ranges make up less than 20 percent and basin flats more than 25 percent of the area, and average range spacing is nearly 31 km. These values represent extremes for the west-central Basin and Range.

Spotted Range-Mine Mountain block - The Spotted Range-Mine Mountain block (SRMM, Fig. 1) is a zone of northeast trending left-lateral faults that ocupies a roughly triangular-shaped area of about 2000 km^2 between the volcanic plateaus of the southern Goldfield block, the Spring Mountains block, and the southeast Great Basin (Carr, 1984). These faults locally cut Quaternary alluvial deposits and displacements are generally less than 2 km (Carr, 1984). The physiography of this small block contrasts sharply with surrounding areas. The ranges are the smallest, lowest, and most closely spaced in the entire west-central Basin and Range; and their east to northeast orientation cuts sharply across the prevailing north to northwest physiographic and structural trends of the region. These contrasts suggest significant differences in tectonic style relative to the surrounding area.

Spring Mountains block - Although also a comparatively small block within the Walker Lane belt, the Spring Mountains (SM, Fig. 1) are very different from the Spotted Range-Mine Mountain block to the north. Among the largest ranges in the region, the Spring Mountains form a high-standing, generally northwest-trending, arcuate upland mass that, together with contiguous piedmont slopes, occupies an area of nearly 4700 km^2. The area of the range itself is approximately 2330 km^2, and average range relief exceeds 1200 m. This block has apparently been relatively undeformed during the Cenozoic (Longwell and others, 1965; Stewart, 1987), and because of this relatively uneventful Cenozoic tectonic history, the range is deeply embayed by large canyons and flanked by broad piedmonts, the highest and widest in the west-central Basin and Range.

Southwest Great Basin - The morphometric characteristics of the southwest Great Basin (SWGB, Fig. 1) indicate that it is probably the youngest and most tectonically active area in the west-central Basin and Range. Ranges occupy about 53% of the domain, the highest proportion of any domain in the region; and with an average relief of 1380 m, these ranges are the tallest in the entire Basin and Range Province. Moreover, the piedmonts fringing these ranges are significantly steeper and proportionally smaller than in any other area of the west-central Basin and Range; piedmont slopes average 6.3 percent, piedmont-width-to-range-width (2Wp/Wr) ratios average 0.71, and piedmont-relief-to-total-relief (Rp/Rt) ratios average 0.17. Not surprisingly, all major basins within the southwest Great Basin are closed. Moreover, the average depth of closure of these basins (about 635 m), is more than three times as deep as in any other area of the province.

Neotectonic activity within the southwest Great Basin is characterized by both normal and strike-slip fault movement (Carr, 1984; Stewart, 1987). The morphology of the range fronts indicates rapid vertical tectonic activity (Hunt and Mabey, 1966; Bull and McFadden, 1977) and as much as 3000 m of late Tertiary and Quaternary deposits fill the intervening basins (Hunt and Mabey, 1966). In addition, several major fault zones with Quaternary strike-slip displacement occur within or along the margins of this domain. 'Basin and range' deformation of this complexly extending area apparently proceeded from east to west and then spread north and south (Schweig, 1986). Uplift and normal faulting started in the Panamint Range before 13 Ma, spread westward to the Argus Range and Inyo Mountains between 8 and 6 Ma, then northward to the Saline Valley-Euerka Valley area between 4.3 and 2.5 Ma (Wrucke and others, 1984; Elliot and others, 1984). Continuing deformation is indicated by the presence of numerous fault scarps in Quaternary alluvium along most major range fronts (Hunt and Mabey, 1966; Hooke, 1972; R. Smith, 1979).

Northern Mojave Desert - The landscape of the northeast Mojave Desert (NCMD and NEMD, Fig. 1) is conspicuously subdued and indicates a general lack, or at least a very low level, of Quaternary tectonic activity. With the notable exception of the Soda Lake basin, basins are small and shallow. The ranges are mostly irregular and discontinuous in overall plan form; and the highly sinuous, deeply embayed range fronts are largely lacking in morphologic evidence of active vertical tectonism. Indeed, most of the range fronts of the northern Mojave region have been classified as inactive (Bull and McFadden, 1977). The morphometry of the region is correspondingly subdued. Except for the smaller blocks of the Walker Lane belt, the ranges are smaller and lower and the piedmonts are higher and broader than in any other area of the west-central Basin and Range. Consequently, piedmont-relief-to-total-relief ratios (Rp/Rt) and piedmont-width-to-range-width ratios (2Wp/Wr) are higher than in any other major tectonic domain.

TECTONIC IMPLICATIONS

Morphometric comparison of the several tectonic domains that make up the west-central Basin and Range clearly demonstrates that these domains are geomorphically distinct. These geomorphic differences likely reflect significant differences in the timing and style of middle to late Cenozoic deformation between these various domains, and they reflect the temporal and spatial discontinuity of tectonic activity within this region.

On the basis of this preliminary morphometric comparison, the several of the major tectonic domains within the west-central Basin and Range can be ranked according to their relative level of neotectonic activity. From most active to least active they are: the southwest Great Basin, the central Great Basin, the southeast Great Basin, and the northern Mojave Desert. However, because of the pronounced physiographic contrasts among its several component blocks, the Walker Lane belt cannot be meaningfully included in this comparative assessment. Indeed, the various blocks of the Walker Lane belt exhibit nearly as much geomorphic variability as occurs throughout the entire region of the west-central Basin and Range. For example, the northeast part of the Goldfield block is morphometrically similar to the northern Mojave Desert, whereas the northwest part of the Goldfield block is, in many ways, similar to the southeast and central parts of the Great Basin.

Juxtaposition of highly active areas against slightly active to inactive areas, both on a subregional scale (e.g. within the Goldfield block of the Walker Lane) and on a regional scale (e.g. the southwest Great Basin against the northern Mojave Desert), is wholly consistent with the notions that these domains are separated by profound structural discontinuities and that deformation within these domains proceeds more or less independently of deformation within adjoining domains. It is somewhat less consistent with the notion of a continuous northward migration in tectonic activity coincident with northward rotation of the Pacific plate and northward migration of the Mendocino triple junction. Whatever the case, it would appear that regional morphometric analysis can provide useful insights regarding the neotectonic history of the Basin and Range Province.

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